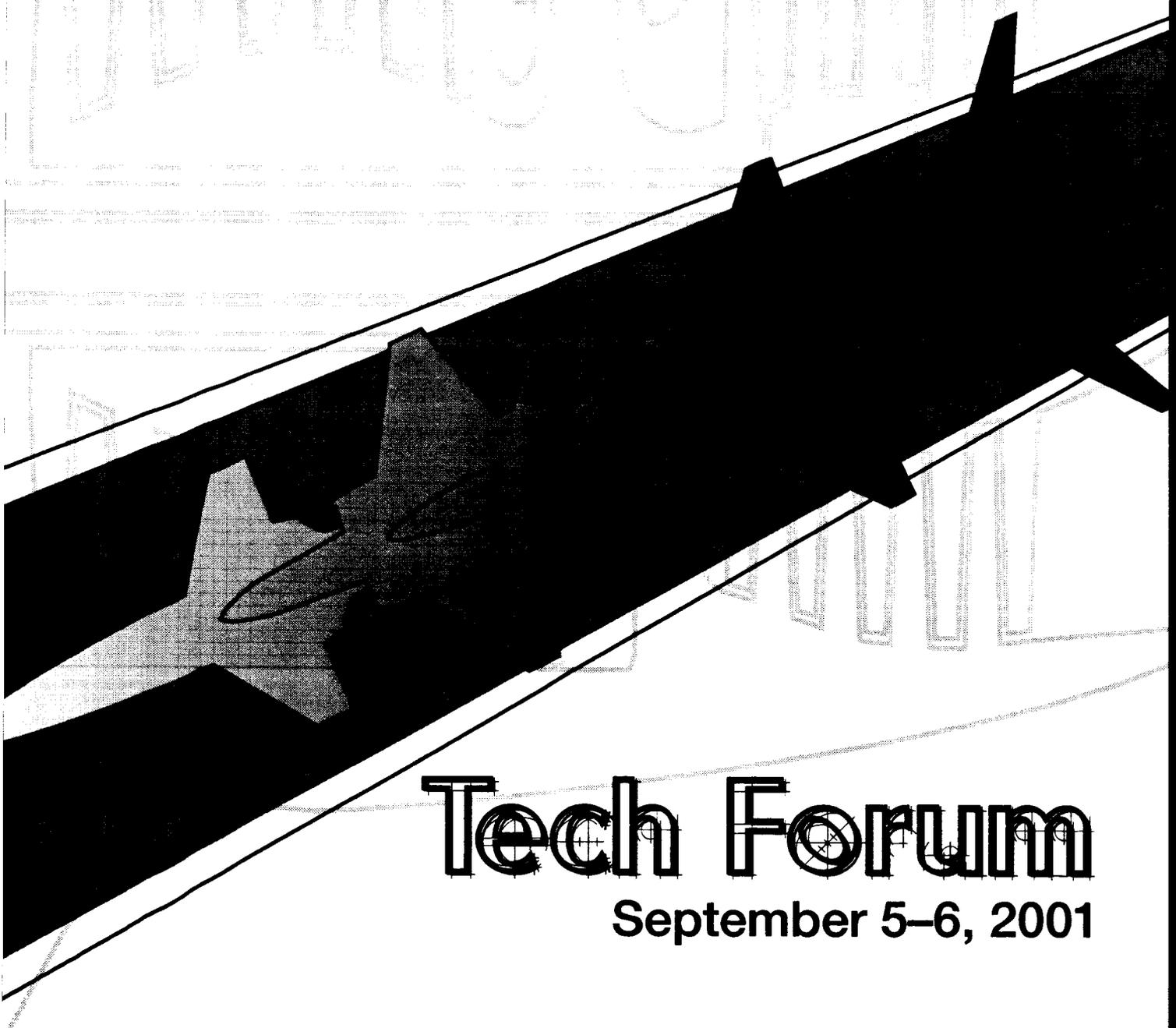


NASA Glenn Research Center

UEET

Ultra-Efficient Engine Technology Program
Agenda and Abstracts



Tech Forum

September 5-6, 2001

UEET Technology Forum Agenda

September 5, 2001

Registration from 7:30 a.m. to 8:30 a.m.

8:00 a.m. 8:05 a.m. 8:10 a.m. 8:15 a.m. 8:20 a.m. 8:25 a.m. 8:30 a.m. 8:35 a.m. 8:40 a.m. 8:45 a.m. 8:50 a.m. 8:55 a.m. 9:00 a.m. 9:05 a.m. 9:10 a.m. 9:15 a.m. 9:20 a.m. 9:25 a.m. 9:30 a.m. 9:35 a.m. 9:40 a.m. 9:45 a.m. 9:50 a.m. 9:55 a.m.	<p>Registration Administration Building Auditorium 7:30 a.m. to 8:30 a.m.</p> <p>Opening Session UEET Overview Robert J. Shaw, Program Manager NASA Glenn Research Center</p> <p>Technology Benefits William Haller</p> <p>Ad Building Auditorium 8:30 to 9:45 a.m.</p> <p>Break 9:45 to 10:00 a.m.</p>	1:00 p.m. 1:05 p.m. 1:10 p.m. 1:15 p.m. 1:20 p.m. 1:25 p.m. 1:30 p.m. 1:35 p.m. 1:40 p.m. 1:45 p.m. 1:50 p.m. 1:55 p.m. 2:00 p.m. 2:05 p.m. 2:10 p.m. 2:15 p.m. 2:20 p.m. 2:25 p.m. 2:30 p.m. 2:35 p.m. 2:40 p.m. 2:45 p.m. 2:50 p.m. 2:55 p.m. 3:00 p.m. 3:05 p.m. 3:10 p.m. 3:15 p.m. 3:20 p.m. 3:25 p.m. 3:30 p.m. 3:35 p.m. 3:40 p.m. 3:45 p.m. 3:50 p.m. 3:55 p.m. 4:00 p.m. 4:05 p.m. 4:10 p.m. 4:15 p.m. 4:20 p.m. 4:25 p.m. 4:30 p.m. 4:35 p.m. 4:40 p.m. 4:45 p.m. 4:50 p.m. 4:55 p.m. 5:00 p.m. 5:05 p.m. 5:10 p.m. 5:15 p.m. 5:20 p.m. 5:25 p.m. 5:30 p.m. 5:35 p.m. 5:40 p.m. 5:45 p.m. 5:50 p.m. 5:55 p.m. 6:00 p.m. 6:05 p.m. 6:10 p.m. 6:15 p.m. 6:20 p.m. 6:25-6:30	<p>Honeywell Low Emissions Combustor Development Terrel Kuhn Honeywell 1:00 to 1:30 p.m.</p> <p>NASA Multipoint LDI Development Robert Tacina NASA Glenn 1:30 to 2:00 p.m.</p> <p>Stanford Activities in Concepts for Advanced Gas Turbine Combustors Chris Edwards Stanford University 2:00 to 2:30 p.m.</p> <p style="text-align: center;">Break 2:30 to 3:00 p.m.</p> <p>Large Eddy Simulation of Gas Turbine Combustion Parviz Moin Stanford University 3:00 to 3:30 p.m.</p> <p>NASA National Combustion Code Simulations Anthony Iannetti Farhad Davoudzadeh NASA Glenn 3:30 to 4:00 p.m.</p> <p>Emissions Reduction Technology Transfer Session 4:00 to 4:45 p.m.</p> <p style="text-align: center;">Break 4:45 to 5:00 p.m.</p>	<p>CMC Material Develop. James DiCarlo NASA Glenn 1:00 to 1:20 p.m.</p> <p>CMC Material Charact. Anthony Calomino NASA Glenn 1:20 to 1:40 p.m.</p> <p>EBC for CMC Materials Kang Lee NASA Glenn 1:40 to 2:00 p.m.</p> <p>CMC Vane Rig Test & Des. Gary Linsey UTRC/Pratt & Whitney 2:00 to 2:20 p.m.</p> <p>UHTC Development Sylvia Johnson NASA Ames 2:20 to 2:40 p.m.</p> <p style="text-align: center;">Break 2:40 to 3:10 p.m.</p> <p>Lightweight Structures J. Daniel Whittenberger NASA Glenn 3:10 to 3:40 p.m.</p> <p>NPARC Alliance James DeBonis NASA Glenn 3:40 to 4:10 p.m.</p> <p style="text-align: center;">Materials Technology Transfer Session 4:10 to 4:55 p.m.</p> <p style="text-align: center;">Reception Visitor Center 5:00 to 6:30 p.m.</p>
10:00 a.m. 10:05 a.m. 10:10 a.m. 10:15 a.m. 10:20 a.m. 10:25 a.m.	<p style="text-align: center;">Emissions Overview John Rohde NASA Glenn 10:00 to 10:30 a.m.</p> <p style="text-align: center;">Materials Overview Robert Draper NASA Glenn 10:00 to 10:30 a.m.</p>		<p style="text-align: center;">P&W Low Emissions Combustor Development Reid Smith Pratt & Whitney 10:30 to 11:00 a.m.</p> <p style="text-align: center;">TBC for Airfoil Applications Robert Miller NASA Glenn 10:30 to 11:00 a.m.</p>	
10:30 a.m. 10:35 a.m. 10:40 a.m. 10:45 a.m. 10:50 a.m. 10:55 a.m.	<p style="text-align: center;">GE Low Emissions Combustor Development Raghavan Pandalai GE Aircraft Engines 11:00 to 11:30 a.m.</p> <p style="text-align: center;">Disk Alloy Development Timothy Gabb John Gayda NASA Glenn 11:00 to 11:30 a.m.</p>		<p style="text-align: center;">Rolls-Royce Low Emissions Combustor Development Nader Rizk Rolls-Royce/Allison 11:30 to Noon</p> <p style="text-align: center;">Turbine Blade Alloy Rebecca MacKay NASA Glenn 11:30 to Noon</p>	
11:00 a.m. 11:05 a.m. 11:10 a.m. 11:15 a.m. 11:20 a.m. 11:25 a.m. 11:30 a.m. 11:35 a.m. 11:40 a.m. 11:45 a.m. 11:50 a.m. 11:55 a.m.	<p style="text-align: center;">Lunch Picnic Grounds Noon to 1 p.m.</p>	<p style="text-align: center;">Lunch Picnic Grounds Noon to 1 p.m.</p>		
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Session in Administration Building Auditorium

Session in Visitor Center Auditorium

UEET Technology Forum Agenda Second Day--September 6, 2001

8:00 a.m.	Turbomachinery Overview Kaz Civinskis NASA Glenn 8:00 to 8:20 a.m.	Propulsion Airframe Integration Overview James L. Pittman NASA Langley 8:00 to 8:30 a.m.	1:00 p.m.	Integrated Components Tech Demos Overview Mary Jo Long-Davis NASA Glenn 1:00 to 1:30 p.m.	Environmental Impact Overview Catherine Peddie NASA Glenn 1:00 to 1:30 p.m.
8:05 a.m.					
8:10 a.m.					
8:15 a.m.					
8:20 a.m.	Efficient Low Noise Fan Brian Fite NASA Glenn Daniel Tweedt AP Solutions, Inc. 8:20 to 8:50 a.m.	Active Flow Control for Inlets Susan A. Gorton NASA Langley 8:30 to 9:00 a.m.	1:30 p.m.	GE UEET System Study & Demo Plan Jorge Seda GE Aircraft Engines 1:30 to 2:00 p.m.	Emissions Inventory Steve Baughcum Don Sutkus Boeing 1:30 to 2:00 p.m.
8:25 a.m.					
8:30 a.m.	UEET Compressor Louis Larosiliere NASA Glenn 8:50 to 9:20 a.m.	Synthetic Jet Actuator Model Development Mark Sheplak, Univ. Florida 9:00 to 9:20 a.m.	1:35 p.m.	PW UEET System Study & Demo Plan Craig Nordeen Pratt & Whitney 2:00 to 2:30 p.m.	Turbine Chemistry Modeling Nan-Suey Liu NASA Glenn 2:00 to 2:30 p.m.
8:35 a.m.					
8:40 a.m.					
8:45 a.m.					
8:50 a.m.	Compressor Flow Control Concepts Michael Hathaway Rod Chima NASA Glenn 9:20 to 9:50 a.m.	CFD Modeling for Active Flow Control Pieter Buning, Langley 9:20 to 9:40 a.m.	2:00 p.m.	Break 2:30 to 3:00 p.m.	Break 2:30 to 3:00 p.m.
8:55 a.m.					
9:00 a.m.					
9:05 a.m.					
9:10 a.m.	Aspiration in Highly Loaded Axial Compressor Design John Adamczyk NASA Glenn 9:50 to 10:20 a.m.	Sensor Development for Active Flow Control Seun Kahng, Langley 9:40 to 10:00 a.m.	2:10 p.m.	Aspirating Seal Demonstration Tom Tseng GE Aircraft Engines 3:00 to 3:30 p.m.	PAGEMS Martin Rabinowitz NASA Glenn 3:00 to 3:30 p.m.
9:15 a.m.					
9:20 a.m.					
9:25 a.m.					
9:30 a.m.	Break 10:20 to 10:30 a.m.	Variable Radius Nacelle Studies David McGowan, Langley 10:30 to 10:50 a.m.	2:20 p.m.	CMC Liner Demonstration Mark Noe GE Aircraft Engines 3:30 to 4:00 p.m.	DERA/NASA Collaboration Rick Miake-Lye Aerodyne Research, Inc. 3:30 to 4:00 p.m.
9:35 a.m.					
9:40 a.m.					
9:45 a.m.					
9:50 a.m.	Status of Glenn-HT Code Applications to Complex Cooling Geometries James Heidmann NASA Glenn 10:30 to 11:00 a.m.	Variable Area Nozzle Development Mike Larkin, P&W 10:50 to 11:10 a.m.	2:25 p.m.	Session in Administration Building Auditorium	Session in Visitor Center Auditorium
9:55 a.m.					
10:00 a.m.					
10:05 a.m.					
10:10 a.m.	Highly Loaded LPT Vithal Dalsania NASA Glenn Milt Ortiz Honeywell 11:00 to 11:30 a.m.	CFD Design for Bypass Ratio 15 Nacelle Integ. William Milholen, Langley 11:10 to 11:30 a.m.	2:30 p.m.	Session in Visitor Center Auditorium	Session in Administration Building Auditorium
10:15 a.m.					
10:20 a.m.					
10:25 a.m.					
10:30 a.m.	MSU-TURBO Enhancements Jen-Ping Chen Mississippi State Univ. Rakesh Srivastava Univ. of Toledo 11:30 to noon	CFD Design of a BWB with BLI Nacelles Melissa Morehouse, LaRC 11:30 to 11:50 a.m.	2:35 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
10:35 a.m.					
10:40 a.m.					
10:45 a.m.					
10:50 a.m.	Lunch Picnic Grounds Noon to 1:00 p.m.	Lunch Picnic Grounds 11:50 to 1:00 p.m.	2:40 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
10:55 a.m.					
11:00 a.m.					
11:05 a.m.					
11:10 a.m.	Lunch Picnic Grounds Noon to 1:00 p.m.	Lunch Picnic Grounds 11:50 to 1:00 p.m.	2:45 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
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11:30 a.m.	Lunch Picnic Grounds Noon to 1:00 p.m.	Lunch Picnic Grounds 11:50 to 1:00 p.m.	2:50 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
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11:50 a.m.	Lunch Picnic Grounds Noon to 1:00 p.m.	Lunch Picnic Grounds 11:50 to 1:00 p.m.	2:55 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
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12:40 p.m.					
12:45 p.m.					
12:50 p.m.	Lunch Picnic Grounds Noon to 1:00 p.m.	Lunch Picnic Grounds 11:50 to 1:00 p.m.	3:10 p.m.	Session in Administration Building Auditorium	Session in Administration Building Auditorium
12:55 p.m.					
12:55 p.m.					
12:55 p.m.					

- Session in Administration Building Auditorium
- Session in Visitor Center Auditorium
- Session in Visitor Center Auditorium
- Session in Administration Building Auditorium

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Ultra-Efficient Engine Technology (UEET) Program Technology Forum Abstracts September 5 and 6, 2001

UEET Overview

Robert J. Shaw

National Aeronautics and Space Administration
Glenn Research Center

NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. One of NASA's 10 Aerospace Technology objectives is to significantly reduce aircraft emissions within 10 years, and the Ultra-Efficient Engine Technology (UEET) Program is working to make this objective a reality.

The UEET program will develop and hand off revolutionary turbine engine propulsion technologies that will enable future generation vehicles over a wide range of flight speeds. The primary goals are to address two of the most critical propulsion issues: performance/efficiency and reduced emissions. High performance, low emissions engine systems will lead to significant improvement in local air quality, minimum impact on ozone depletion, reduction in fuel consumption, and an overall reduction in the aviation contribution to global warming.

The UEET Program, managed by the Glenn Research Center in Cleveland, Ohio, includes participation from three other NASA centers (Ames, Goddard, and Langley), as well as five engine companies (GE Aircraft Engines, Pratt & Whitney, Honeywell, Allison/Rolls Royce, and Williams International) and two airplane manufacturers (Boeing and Lockheed Martin). In addition, strategic partnerships are being formed with the Department of Defense and DARPA, the Department of Energy, the Environmental Protection Agency, the Federal Aviation Administration, as well as key universities, on technology development and technology requirements definition.

Notes

Technology Benefits
Systems Assessment of UEET Technologies
William Haller
National Aeronautics and Space Administration
Glenn Research Center

An assessment was recently performed by NASA's Inter-Center Systems Analysis Team to quantify the potential emission reduction benefits from technologies being developed under UEET. The CO₂ and LTO NO_x reductions were estimated for 4 vehicles: a 50-passenger regional jet, a twin-engine, long-range subsonic transport, a high-speed (Mach 2.4) civil transport and a supersonic (Mach 2) business jet. The results of the assessment confirm that the current portfolio of technologies within the UEET program provides an opportunity for substantial reductions in CO₂ and NO_x emissions.

Notes

Emissions Overview
Overview of the Emissions Reduction Project of the UEET Program
John Rohde
National Aeronautics and Space Administration
Glenn Research Center

The Emissions Reduction Project is working in close partnership with the U.S. aircraft engine manufacturers and academia to develop technologies to reduce NO_x emissions by 70 percent over the LTO cycle from 1996 ICAO standards with no increase in other emission constituents (carbon monoxide, smoke, and unburned hydrocarbons) and with comparable NO_x reduction during cruise operations. These technologies cannot impact the overall combustor and fuel delivery system operability, affordability or maintainability. These new combustion concepts and technologies will include lean burning combustors with higher operating gas temperatures and pressures, fuel staging, ceramic matrix composite material liners with reduced cooling air and possibly advanced controls.

Improved physics-based analysis tool will be developed and validated and some longer term technologies that are more revolutionary will be assessed. These improved computational codes will provide improved design tools to increase design confidence and cut the development time to achieve major reductions in NO_x emissions. Longer term, revolutionary technologies like active combustion controls, combustion from a large array of micro-injectors, electrostatic fuel injectors, fuel additives and others will be investigated and assessed through proof-of-concept testing.

Notes

P&W Low Emissions Combustor Development
Emissions Reduction: P&W Program Review and Plan
Reid Smith
Pratt & Whitney

In conjunction with development of the TALON (Technology for Advanced Low NO_x) family of reduced emissions combustors, Pratt & Whitney is investigating both Rich Quench Lean (RQL) and Lean Direct Injection (LDI) approaches toward achieving the NASA UEET program goal of 70 percent reduction in Landing/Take-off cycle NO_x relative to the 1996 CAEP/2 standard. Based upon previous AST and UEET testing, candidate concepts that have the potential to satisfy the NO_x goal have been selected for further investigation. The simple, unstaged TALON III RQL combustor is most advanced in the technology development cycle, currently completing sector rig testing with annular rig evaluation scheduled for 1Q2002. The second generation (following initial investigation under AST) of TALON IV LDI and Reduced Scale Quench (RSQ) RQL flametube combustors are either at test (LDI) or building for test (RSQ) with arc sector rig testing scheduled to begin 2Q2002. As an enabler for NO_x reduction, Pratt & Whitney has successfully completed a program to identify approaches for reducing advanced metallic liner cooling requirements by up to 50 percent, freeing air for emissions control processes. These cooling technologies are being incorporated in current and planned rig tests.

Notes

GE Low Emissions Combustor Development

Raghavan Pandalai
GE Aircraft Engines

The GE UEET program activity has been focused on continuing the development of the revolutionary TAPS mixer. The TAPS design was first conceived during the Advanced Subsonic Technology (AST) program and has undergone continued development in GE's TECH56 program. The TAPS system is a very practical design that fits easily into current engine architecture. TAPS has demonstrated the capability to achieve NO_x reductions 50 to 60 percent below CAEP/2 requirements for cycles in the 25 to 40 OPR range as well as meeting all other engine operational requirements. Current UEET activity is targeted toward improving the TAPS cyclone mixing. When complemented by cooling technology advances, this will allow the system to achieve NO_x reductions 70 percent below CAEP/2 for UEET study cycles. The presentation material gives an overview of the cyclone design and selection process, summarizes the results from fired screening tests, outlines future testing at NASA, and reviews proposed plans for continued design development.

Notes

Rolls-Royce Low Emissions Combustor Development
Low Emission Combustor for Regional Engines

Nader Rizk
Rolls-Royce Corporation

The objective for this program is to develop low emissions combustion systems, and integrate those systems into turbofan engines for subsonic defense systems and commercial regional applications. The progress made so far involved the development of two combustor concepts through testing in flametube, sector, and full combustor configurations. The testing of the full combustor under advanced regional engine cycles demonstrated more than 50 percent NO_x reduction from the 1996 ICAO. To meet the UET 70 percent NO_x reduction goal, a concentric fuel-staged injector was tested in a flametube. This concept will be used in the combustor sector to be developed during the next 18 months. The effort made under this program supports Level I milestones 13, 14, 15, 16, 18, and 22.

Notes

Honeywell Low Emissions Combustor Development

Low Emissions Combustor Development

Terrel Kuhn

Honeywell Engines & Systems

Honeywell Engines & Systems is currently developing combustor technologies for regional air transport turbofan engines that will enable 70 percent reductions in NO_x emissions. The lowest risk concept is lean-direct fuel injection (LDI), wherein the main fuel is partially premixed before entering the main combustion chamber. The LDI design is being optimized using laser diagnostic techniques in preparation for flametube and sector rig tests at NASA Glenn and full annular rig tests at Honeywell. Honeywell is working actively with a multipoint LDI fuel injection technology being developed by NASA Glenn to assure applicability of the technology to a regional turbofan application. A third concept that integrates the diffuser and the combustor will be studied.

Notes

NASA Multipoint LDI Development
MultiPoint Lean Direct Injection (LDI) Low NO_x Combustor
Robert Tacina
National Aeronautics and Space Administration
Glenn Research Center

Multipoint Lean-Direct-Injection (LDI) is a combustor concept in which a large number of fuel injectors and fuel-air mixers are used to quickly and uniformly mix the fuel and air so that ultralow levels of NO_x are produced. Each fuel injector has an air swirler associated with it for fuel-air mixing and to establish a small recirculation and burning zone. A concept in which there are 36 fuel injectors in the space of a conventional single fuel injector has been tested in a flame tube. A greater than 80 percent reduction in NO_x at high power conditions (400 psia, 1000 °F inlet) was achieved. Alternate concepts with 9, 25, 36 or 49 fuel injectors are being investigated in flame tube tests for their low NO_x potential and with fuel staging to improve the turndown ratio at low power conditions. A preliminary sector concept of a large engine design has been successfully tested at inlet conditions of 700 psia and 1100 °F. This concept had one half the number of fuel injectors per square inch as the flame tube configuration with 36 fuel injectors, and the NO_x reduction was 65 percent of the ICAO standard. Future regional engine size sector tests are planned for the 2nd quarter of FY02 and large engine size sector tests for the 1st quarter of FY03.

Notes

Stanford Activities In Concepts for Advanced Gas Turbine Combustors

Chris Edwards
Stanford University

This presentation reports the activities of a coordinated program of research to improve the efficiency and reduce emissions of aircraft gas turbine engines through innovative concepts for gas turbine combustion. Activities are in progress in four areas: (1) combustor measurements for development and validation of LES methods for gas turbine combustor simulations, (2) LES simulations of gas-phase combustion and spray combustion, (3) construction and testing of a temporally modulated spray injector for use in the study and control of combustion instability, and (4) development and testing of mesoscale injector arrays for use in gas turbine combustors.

Combustor measurements using gaseous fuel have been completed and liquid-fuel tests are now in progress. Measurements include mean temperature, major species, and two-component velocity mapping, and spray characterization in both combusting and cold-flow cases. Large Eddy Simulations (LES) of the combustor flow field are reported in a companion paper at this forum.

Results are reported on development and characterization of a temporally modulated liquid fuel injector that has a size distribution function and cone angle that are independent of modulation frequency. This injector will provide a well-defined actuator for use in experimental and computational studies of combustion control.

The mesoscale injector array is a spatial analog to the temporally modulated injector. It produces compact/distributed, nearly premixed flames that have the potential to replace conventional approaches to combustion in both main-burner and turbine-reheat applications with significant performance improvements and emissions reductions. Results of prototype testing are reported.

Notes

Large Eddy Simulation (LES) of Gas Turbine Combustion

Combustion Simulation Using LES

Parviz Moin
Stanford University

Two new approaches to chemistry modeling for large eddy simulation (LES) of turbulent reacting flows are developed. Both approaches use the flamelet library and therefore include full complex chemistry. The progress variable approach, which maps the detailed chemical processes to a reduced set of tracking scalars, has been applied to a methane jet combustor for which experimental data is available. The progress variable approach is able to capture the unsteady, lifted flame dynamics observed in the experiment, to obtain good agreement with the experimental data, and to significantly out-perform the fast chemistry and steady flamelet models, which both predict an attached flame.

The unsteady flamelet approach is the alternative method that is being developed in parallel at CTR for LES of turbulent combustion. The unsteady flamelet equations are solved simultaneously with the flow and scalar equations to account for transient chemical effects. These transient effects have been shown to be very important for prediction of pollutants such as nitrous oxides and smoke. This technique has been applied to the so-called Sandia Flame D, and the agreement of temperature and species concentrations with the data is excellent.

The CTR program also includes a large effort in the development of numerical methods and codes for LES of turbulent combustion in complex geometry. An unstructured mesh code has been developed for parallel computer platforms. The numerical method is non-dissipative, which has been shown to be a critical property for LES. This code has been applied to a combustor sector of PW6000. In addition, a new numerical method for low Mach number flows capable of accurately resolving long wavelength acoustic waves responsible for combustion instabilities has been developed.

Notes

NASA National Combustion Code Simulations

Validation of the National Combustion Code (NCC)

Anthony Iannetti

National Aeronautics and Space Administration
Glenn Research Center

Farhad Davoudzadeh

Sest, Inc.

A systematic effort is in progress to further validate the National Combustion Code (NCC) that has been developed at NASA Glenn Research Center (GRC) for comprehensive modeling and simulation of aerospace combustion systems. The validation efforts include numerical simulation of the gas-phase combustor experiments conducted at the Center for Turbulence Research (CTR), Stanford University, followed by comparison and evaluation of the computed results with the experimental data. Presently, at GRC, a numerical model of the experimental gaseous combustor is built to simulate the experimental model. The constructed numerical geometry includes the flow development sections for air annulus and fuel pipe, 24 channel air and fuel swirlers, hub, combustor, and tail pipe. Furthermore, a three-dimensional multi-block, multi-grid grid (1.6 million grid points, 3-levels of multi-grid) is generated. Computational simulation of the gaseous combustor flow field operating on methane fuel has started. The computational domain includes the whole flow regime starting from the fuel pipe and the air annulus, through the 12 air and 12 fuel channels, in the combustion region and through the tail pipe.

Notes

Materials Overview
Materials and Structures for High Performance
Robert Draper
National Aeronautics and Space Administration
Glenn Research Center

The Materials and Structures for High Performance project has made excellent progress in the development of advanced high-temperature materials and computational materials science tools to enable high-performance, high-efficiency, and environmentally compatible propulsion systems. Ceramic matrix composite (CMC) systems with 2700 °F temperature capability are initially being developed for low NO_x combustor liners and turbine vanes. The feasibility of pushing CMC technologies to 3000 °F through revolutionary concepts is also being pursued. Achieving fuel savings of 8 to 15 percent requires higher turbine inlet temperatures as well as reductions in engine weight. An advanced disk alloy has been evaluated for application in future engines. Advanced thermal barrier coatings (TBC's) will enable 3200 °F turbine rotor inlet temperature capability. Advanced alloy development and the development of computational tools for the design of these future alloys will further enable attainment of these goals.

Innovative lightweight materials, and structural and nozzle aerodynamic concepts are also being developed to reduce the weight of engine static structures to contribute toward overall fuel savings. Rig tests will demonstrate long-term durability of CMC liners and vanes and advanced turbine airfoil alloy systems, as well as fabricability of components with the highest payoff potential using the lightweight materials and structures concepts being developed.

Notes

Thermal Barrier Coatings for Airfoil Applications

Robert A. Miller and Dongming Zhu
National Aeronautics and Space Administration
Glenn Research Center

Thermal barrier coatings having significantly reduced thermal conductivities are being developed under this program. The conductivities, after 20 hours of sintering under high heat flux exposure in a unique laser rig test, are reduced to nearly 1/3 of the state-of-the-art baseline value for the plasma sprayed coatings and to 1/2 of the baseline for the physical vapor-deposited coatings. The coatings consist of zirconia-yttria with relatively small additions of certain rare earth oxides. Further conductivity reductions and cyclic life optimization are planned for the coming year.

Notes

Disk Alloy Development
Advanced Disk Alloys ME3 and Alloy 10
Tim Gabb, John Gayda, and Jack Telesman
National Aeronautics and Space Administration
Glenn Research Center

The advanced powder metallurgy disk alloy ME3 was designed using statistical screening and optimization of composition and processing variables in the NASA HSR/EPM disk program to have extended durability at 1150 to 1250 °F in large disks. Scaled-up disks of this alloy were produced at the conclusion of this program to demonstrate these properties in realistic disk shapes. The objective of the UEET disk program was to assess the mechanical properties of these ME3 disks as functions of temperature, in order to estimate the maximum temperature capabilities of this advanced alloy. Scaled-up disks processed in the HSR/EPM Compressor/Turbine Disk program were sectioned, machined into specimens, and tested in tensile, creep, fatigue, and fatigue crack growth tests by NASA Glenn Research Center, in cooperation with General Electric Engine Company and Pratt & Whitney Aircraft Engines. Additional sub-scale disks and blanks were processed and tested to explore the effects of several processing variations on mechanical properties. Scaled-up disks of an advanced regional disk alloy, Alloy 10, were used to evaluate dual microstructure heat treatments. This allowed demonstration of an improved balance of properties in disks with higher strength and fatigue resistance in the bores and higher creep and dwell fatigue crack growth resistance in the rims. Results indicate the baseline ME3 alloy and process has 1300 to 1350 °F temperature capabilities, dependent on detailed disk and engine design property requirements. Chemistry and process enhancements show promise for further increasing temperature capabilities.

Notes

Turbine Blade Alloy
Advanced Single Crystal Nickel Base Superalloy For Turbine Blades
Rebecca MacKay
National Aeronautics and Space Administration
Glenn Research Center

The High Speed Research Airfoil Alloy Program developed a fourth-generation alloy with up to an +85 °F increase in creep rupture capability over current production airfoil alloys. Since improved strength is typically obtained when the limits of microstructural stability are exceeded slightly, it is not surprising that this alloy has a tendency to exhibit microstructural instabilities after high temperature exposures. This presentation will discuss recent results obtained on coated fourth-generation alloys for subsonic turbine blade applications under the NASA Ultra-Efficient Engine Technology (UEET) Program. Progress made in reducing microstructural instabilities in these alloys will be presented. In addition, plans will be presented for advanced alloy development and for computational modeling, which will aid future alloy development efforts.

Notes

Ceramic Matrix Composite (CMC) Materials Development

James DiCarlo

National Aeronautics and Space Administration
Glenn Research Center

Under the former NASA EPM Program, much initial progress was made in identifying constituent materials and processes for SiC/SiC ceramic composite hot-section components. This presentation discusses the performance benefits of these approaches and elaborates on further constituent and property improvements made under NASA UEET. These include specific treatments at NASA that significantly improve the creep and environmental resistance of the Sylramic™ SiC fiber as well as the thermal conductivity and creep resistance of the CVI SiC matrix. Also discussed are recent findings concerning the beneficial effects of certain 2D-fabric architectures and carbon between the BN interphase coating and SiC matrix.

Notes

Ceramic Matrix Composite (CMC) Materials Characterization

Physical Characterization 9/99 and 01/01 Sylramic/SiC/MI

Anthony Calomino

National Aeronautics and Space Administration

Glenn Research Center

A statistically robust characterization of the physical properties, time-dependent behavior, environmental durability, and high cycle fatigue response of the 9/99 melt infiltration ceramic matrix composite at temperatures up to 2400 °F is complete. Factors affecting the potential commercial implementation of this material are shown to have a strong relationship with processing reliability and reproducibility at temperatures below 2200 °F. At temperatures above 2200 °F, the creep and environmental durability material constituents limit material performance. Preliminary mechanical characterization results on UEET's 2400 °F higher temperature ceramic matrix composite, termed the 01/01 material, will be discussed.

Notes

**Environmental Barrier Coatings (EBC) for
Ceramic Matrix Composite (CMC) Materials**
Characterization of Enabling Propulsion Materials (EPM) EBC and Development of New EBC
Kang Lee
National Aeronautics and Space Administration
Glenn Research Center

The upper use temperature of current Environmental Barrier Coatings (EBC's) based on mullite and BSAS (EPM EBC's) is limited to ~255 °F due to silica volatility, chemical reactions, and high thermal conductivity. Therefore, new EBC's having low CTE, good chemical compatibility, and high melting point (>2700 °F) are being investigated. Sinter-resistant, low thermal conductivity EBC's are strongly desired to achieve the UEET EBC goal of 270 °F EBC surface temperature and 30 °F ΔT over long exposures (> 1000 hr). Key areas affecting the upper temperature limit of current EBC's as well as the ongoing efforts to develop next generation EBC's in the UEET Program will be discussed.

Notes

Ceramic Matrix Composite Vane Rig Testing and Design
CMC Vane Design and 2700 °F EBC Development
Gary Linsey
United Technologies Research Center (UTRC)

Under the NASA-funded Ultra-Efficient Engine Technology (UEET) program, the United Technologies Research Center (UTRC) has begun designing Ceramic Matrix Composite (CMC) turbine vanes with an Environmental Barrier Coating (EBC) capable of withstanding 2700 °F surface temperature and 2400 °F interface temperature for over 1,000 hours in turbine engine environments. The CMC turbine vanes consist of silicon carbide fiber-reinforced silicon carbide (SiC/SiC) material with a Celsian-based EBC similar to the system which has demonstrated over 27,000 hours of successful engine field testing under various DOE-funded programs.

Notes

Ultra-High Temperature Ceramic (UHTC) Development
Development of Ultra-High Temperature Ceramics for Gas Turbine Applications

Sylvia Johnson and Don Ellerby
National Aeronautics and Space Administration
Ames Research Center

During the last decade, NASA Ames has been developing new, Ultra-High Temperature Ceramic (UHTC) materials for Thermal Protection Systems applications. The UHTC's are a family of materials including compositions of HfB_2 and ZrB_2 with a SiC second phase. A collaboration with Glenn was recently initiated to evaluate the viability of some UHTC materials that had been produced by an outside vendor for use in gas turbine engine environments. Results from this collaboration have indicated that compositions based on HfB_2 show the most promise, among the UHTC compositions evaluated, for use in these environments. Work at ARC has been initiated to fabricate these materials in-house and evaluate methods of improving their properties for use in engine environments.

Notes

Lightweight Structures

J. Daniel Whittenberger
National Aeronautics and Space Administration
Glenn Research Center

Present structural concepts for hot static structures are conventional “sheet & stringer” or truss core construction. More weight-efficient concepts such as honeycomb and lattice block are being investigated, in combination with both conventional superalloys and TiAl. Development efforts for components made from TiAl sheet are centered on lower cost methods for sheet and foil production, plus alloy development for higher temperature capability. A low-cost casting technology recently developed for aluminum and steel lattice blocks has demonstrated the required higher strength and stiffness, with weight efficiency approaching honeycombs. The current effort is based on extending the temperature capability by developing lattice block materials made from IN-718 and Mar-M247.

Notes

NPARC Alliance
The National Project for Application-oriented Research in CFD (NPARC) Alliance
Flowfield Simulation System

James R. DeBonis
National Aeronautics and Space Administration
Glenn Research Center

The NPARC Alliance is a cooperative effort between the United States Air Force's Arnold Engineering Development Center, NASA's Glenn Research Center and The Boeing Company. The mission of the Alliance is to develop, validate, and support an integrated, general purpose computational flow simulator for the U.S. aerospace community. The Alliance provides a state of the art simulation system that includes geometry manipulation, flow solution, and post-processing capabilities. The system is centered around the WIND flow solver. This presentation provides an overview of the Alliance and the flowfield simulation system. Several example computations are provided.

Notes

Technology Transfer and Commercialization

Katherine Martin and Diane Chapman
National Aeronautics and Space Administration
Glenn Research Center

Melanie Griffith and Darwin Molnar
National Technology Transfer Center

During concurrent sessions for Materials and Structures for High Performance and Emissions Reduction, the UEET Intellectual Property Officer and the Technology Commercialization Specialist will discuss the UEET Technology Transfer and Commercialization goals and efforts. This will include a review of the Technology Commercialization Plan for UEET and what UEET personnel are asked to do to further the goals of the Plan. The major goal of the Plan is to define methods for how UEET assets can best be infused into industry. The National Technology Transfer Center will conduct a summary of its efforts in assessing UEET technologies in the areas of materials and emissions reduction for commercial potential. NTTC is assisting us in completing an inventory and prioritization by commercialization potential. This will result in increased exposure of UEET capabilities to the private sector. The session will include audience solicitation of additional commercializable technologies.

Notes

Turbomachinery Overview

Kestutis Civinskas

U.S. Army Research Laboratory

National Aeronautics and Space Administration

Glenn Research Center

One of the UEET program goals is to provide propulsion technologies to enable a 15 percent reduction in CO₂ emissions (relative to the best-in-service systems in 1999) for large subsonic transports and 8 percent for supersonic and/or small aircraft. The Highly-Loaded Turbomachinery Project is providing the enhanced turbomachinery capability and efficiency to enable the higher overall cycle pressure ratios and turbine inlet temperatures required to meet these overall fuel burn and CO₂ reduction goals. The technologies are relevant to a wide range of flight speed and size-class applications. While some work builds upon earlier efforts (AST, HSR, Propulsion Base), this project is largely a new start to explore and develop some radical turbomachinery capability with low starting TRL.

This project focuses on fan, compressor, and turbine technologies for reduced-stage, efficient but lightweight cores, low-pressure (LP) spools, and propulsors for highly efficient and environmentally compatible propulsion systems. Concepts for significantly increased aerodynamic loading of turbomachinery, trailing edge wake control, and incorporation of highly effective cooling will be developed and demonstrated. Fan technology development will be collaboratively worked with the QAT Program to maintain efficiency while satisfying reduced noise goals. Flow control techniques are being explored for fan, compressor and turbine components and selected concepts will be demonstrated through proof-of-concept tests. Physics-based models for flow control and cooling will be developed and validated. Advanced CFD codes with physics-based models incorporated will be applied to select promising concepts and to design component hardware for rig test demonstrations of fan, core compressor, and HP/LP turbine systems to reach TRL 3-4.

Notes

Efficient Low Noise Fan Overview and Preliminary Aerodynamic Design

Brian Fite and Daniel Tweedt
National Aeronautics and Space Administration
Glenn Research Center

With support from the Ultra-Efficient Engine Technology (UEET) and Quiet Aircraft Technology (QAT) programs, an efficient low noise fan will be designed and tested to investigate aerodynamic and acoustic performance effects using trailing edge blowing (TEB). The fan uses TEB to fill the momentum deficit behind the fan rotor. This presentation will include an overview of the plan to design, build, and test the fan in the NASA Glenn Research Center 9- by 15-Foot Low-Speed Wind Tunnel. In addition, the preliminary aerodynamic design will be presented.

Notes

UEET Compressor
Development of Advanced Compressor Aero Design Technology for UEET
Louis M. Larosiliere
U.S. Army Research Laboratory
National Aeronautics and Space Administration
Glenn Research Center

Turbocompression technology has been advanced continuously by higher work capacity per stage owing to increases in rotor speed, aerodynamic loading, and throughflow Mach numbers. Using sophisticated diagnostic tools involving CFD and measurement techniques, more suitable blade shapes, with relatively low losses at higher diffusion and Mach number levels, have been deployed. The quest for further aerodynamic performance advancements is becoming progressively more difficult due to a dwindling residue of losses. A vital issue is whether to advance by refining and extending well-proven concepts, perhaps in the face of diminishing returns, or by changing to something more unpredictable yet inviting.

A program is being conducted by the Glenn Research center to study and develop advanced design concepts that will enable compact, high-efficiency, wide-operability compressors. This is a direct response to the need for further performance gains from current turbomachinery systems. A combination of evolutionary and revolutionary approaches to technology development has been adopted. The evolutionary approach employs advancements in simulation techniques to refine traditional design concepts in a bid for higher efficiencies at increased aerodynamic loading levels, whereas the revolutionary approach attempts to explore unconventional concepts and paradigms for increased pressure ratio, higher efficiencies, and wider operability.

This presentation starts by describing the level of technical advancement being sought and quantifying the advancement in terms of basic aerodynamic technology elements of current design systems. An outline of the preliminary aerodynamic design of a 4-stage core compressor configuration having the potential to integrate and demonstrate these advancements is given. The front two stages of the 4-stage configuration were further developed using the best available CFD tools. A three-dimensional viscous inverse design method was used to define transonic rotor blading, and the design considerations are discussed. This serves to illustrate achievable performance using an evolutionary approach buttressed by advanced turbomachinery CFD.

Notes

Compressor Flow Control Concepts

I. Advanced Casing Treatment

Michael D. Hathaway

U.S. Army Research Laboratory

National Aeronautics and Space Administration

Glenn Research Center

The goal of this research program was to develop an improved casing treatment concept for application to high-speed compressors which improves on existing capabilities. As such, a state-of-the-art CFD code (APNASA) was employed in a computationally based parametric investigation of the impact of casing suction and injection on the stability and performance of a low-speed fan rotor wherein the stalling massflow was controlled by tip flow field breakdown. The parametric investigation was guided by observed trends in end wall flow characteristics as stall is approached, and based on the hypothesis that application of suction or blowing can mitigate these trends. The best suction and injection configurations were then combined to yield a self-recirculating casing treatment concept which improves on existing recirculating casing treatment designs. The results of this parametric investigation yielded (1) identification of the fluid mechanisms which precipitate stall of tip critical blade rows, and (2) an approach to recirculated casing treatment design which produces benefits in both compressor stall range and efficiency. Subsequent application of this approach to a high speed transonic rotor successfully yielded similar improvements in stall range with no loss in compressor efficiency.

Notes

Compressor Flow Control Concepts
II. UEET Compressor Flow Control Modeling
Rodrick V. Chima
National Aeronautics and Space Administration
Glenn Research Center

Several passive flow control devices have been modeled computationally in the Swift CFD code. The models were applied to the first stage rotor and stator of the baseline UEET compressor in an attempt to improve efficiency and/or stall margin. The devices included suction surface bleed, tip injection, self-aspirated rotors, area-ruled casing, and vortex generators. The models and computed results will be described in the presentation. None of the results have shown significant gains in efficiency; however, casing vortex generators have shown potential improvements in stall margin.

Notes

Aspiration in Highly Loaded Axial Compressor Design

MIT/NASA Glenn Aspirated Four Stage Compressor

John Adamczyk

National Aeronautics and Space Administration

Glenn Research Center

NASA's objectives for the Ultra-Efficient Engine Technology (UEET) program include the demonstration of compression systems with increased work per stage and higher efficiency relative to current practice. One concept being proposed to achieve this objective is to aspirate the high loss, viscous layers from the compressor blading. Recent work under a DARPA sponsored program to design a very highly loaded fan stage using the aspiration concept coupled with a unique inverse design technique has indicated that significantly increased loading levels can be obtained at good efficiency levels. The present effort will apply this same aspiration concept to design axial compressor blading capable of delivering a 12:1 pressure ratio in four axial stages at 1250 ft/sec design tip speed.

Notes

Status of Glenn-HT Code Applications to Complex Cooling Geometries

James Heidmann

National Aeronautics and Space Administration
Glenn Research Center

The Glenn-HT code is a 3D Navier-Stokes solver that has been used and validated for a variety of convective heat transfer problems associated with turbine flows. These flows have included tip clearance, simplified internal cooling, and film cooling. The multi-block capability of the code makes it particularly useful for the complex geometries of such flows.

One of the goals of the UEET program is to reduce turbine cooling flow while increasing turbine inlet temperature. The Glenn-HT code gives researchers a tool to analyze the flow within the very complicated geometries associated with actual cooled turbine designs. Through these analyses and their comparison with experimental data, it is hoped to extend the applicability of the Glenn-HT code for use as a tool to improve turbine cooling designs to meet UEET goals.

Notes

Highly Loaded Low Pressure Turbine (LPT)

Aspirated Low Pressure Turbine

Milt Ortiz and Vithal Dalsania

National Aeronautics and Space Administration

Glenn Research Center

The goal of this study is to evaluate aspirated and nonaspirated aerodynamics on highly loaded LPT design. The objective is to increase stage loading by 30 to 50 percent without loss of efficiency for an existing low pressure turbine design. A study conducted on a NASA highly loaded multistage fan drive turbine (NASA CR-1964) indicated that end-wall bleed at the hub is a more significant parameter compared to aspirated airfoil. Based on this study, a 3-stage LPT is redesigned to 2-stage LPT with and without end-wall bleed. Both aerodynamic design and mechanical design are completed. In addition to end-wall bleed, exit guide vanes are designed with aspirated airfoils to reduce the losses. The LPT is redesigned with all constraints necessary for practical application. The benefit of the high-performance, highly loaded LPT shows up in reduced stage and part count, reduced size and weight, and reduced cost.

Notes

MSU-TURBO Enhancements
I. Enhancements and Validation Overview
Jen-Ping Chen
Mississippi State University

Numerical simulation of the unsteady flows between multiple stages in turbomachinery has become a desired method to help in the understanding of the complex flows found in modern compressor designs. The computation of complete flow fields involving multiple blades typically requires a tremendous amount of computing resources, which soon exceeds that which can be provided by most single-processor supercomputers.

A high-fidelity computer simulation of the complete four-stage UEET compressor will greatly aid in the development of this advanced technology. Parallel computing provides a practical way for such large-scale simulations. A parallel code based on a serial version of the TURBO code was developed. This code inherited most of the features found in the serial TURBO code. It was made to support general blocking domain decomposition, which will greatly aid in resolving details of the flow field.

Thus far, validation has been by comparing results from the serial and parallel codes using NASA Stage 37. Computation of a 1.5-stage UEET initial design was also compared to the APNASA results. Estimated parallel efficiency of this code is about 85 percent.

Notes

MSU-TURBO Enhancements

II. Aeroelastic Stability Analysis

Rakesh Srivastava
University of Toledo

Modern turbomachinery blade designs with forward sweep and lean are being used to improve the noise characteristics. These geometric features coupled with the presence of shock can lead to flutter instability. Accurate calculation of flutter stability for the modern blade geometry requires a three-dimensional viscous aeroelastic analysis. An aeroelastic version of the serial MSU-TURBO code has been developed and has been applied to modern fan and compressor blade designs. Results obtained for a transonic forward swept fan have shown good comparison with experimental measurements. Analysis of UEET compressor Rotor-2 has indicated the rotor to be stable.

Notes

Propulsion Airframe Integration Overview

James L. Pittman

National Aeronautics and Space Administration

Langley Research Center

The Propulsion Airframe Integration (PAI) Project develops advanced technologies to yield lower drag integration of the propulsion system with the airframe. Lower drag reduces aircraft fuel burn for a given mission, and therefore contributes to the UET Program's 15 percent CO₂ emission reduction goal for large commercial jet transports. An overview of the PAI technologies and plans is given in this presentation.

Notes

Active Flow Control For Inlets

Susan A. Gorton

National Aeronautics and Space Administration

Langley Research Center

This presentation describes the progress to date of the Small-Scale Demonstration for the Active Flow Control element of the Propulsion Airframe Integration Project. The goal of this work package is to demonstrate at small scale the ability to improve pressure recovery and distortion in an S-inlet with boundary layer ingestion representative of a Blended Wing Body (BWB) configuration. The effectiveness of several active and passive devices to control flow in an adverse pressure gradient with secondary flows present was evaluated in the Langley 15-Inch Low-Turbulence Tunnel. In this study, passive microvanes, microbumps, and piezoelectric synthetic jets were evaluated for their flow control characteristics using surface static pressures, flow visualization, and 3D Stereo Digital Particle Image Velocimetry. The microvanes imparted a higher level of vorticity to the flow than any of the other devices tested. Alternative actuator concepts are being pursued to support the Small-Scale Demonstration Level 1 milestone in FY03.

Notes

Synthetic Jet Actuator Model Development

Lou Cattafesta and Mark Sheplak
University of Florida

This presentation describes the progress during the first year of a three year grant to develop a theoretical model of a synthetic jet actuator. Lumped element methodology is applied to arrive at an equivalent circuit representation of the synthetic jet. Each of the individual components of the jet are identified and modeled as the components of an equivalent electrical circuit. Using this approach, the synthetic jet design can be optimized for specific performance, and the transfer function of the circuit gives an indication of the response of the synthetic jet. This presentation will describe the lumped element equivalent circuit, the components of the synthetic jet that are modeled, and the validation of several of the circuit components. Comparison of the method to preliminary data will also be presented.

Notes

CFD Modeling for Active Flow Control

Pieter G. Buning

National Aeronautics and Space Administration

Langley Research Center

This presentation describes current work under UEET Active Flow Control CFD Research Tool Development. The goal of this work is to develop computational tools for inlet active flow control design. This year's objectives were to perform CFD simulations of fully gridded vane vortex generators, micro-vortex generators, and synthetic jets, and to compare flowfield results with wind tunnel tests of simple geometries with flow control devices. Comparisons are shown for a single micro-vortex generator on a flat plate, and for flow over an expansion ramp with sidewall effects. Vortex core location, pressure gradient and oil flow patterns are compared between experiment and computation. This work lays the groundwork for evaluating simplified modeling of arrays of devices, and provides the opportunity to test simple flow control device/sensor/control loop interaction.

Notes

Sensor Development for Active Flow Control

Seun K. Kahng, Susan A. Gorton, Johnney C. Mau,
and Hector L. Soto

National Aeronautics and Space Administration
Langley Research Center

Corey D. Hernandez
Swales Aerospace, Inc.

Presented are the developmental efforts for MEMS sensors for a closed-loop active flow control in a low-speed wind tunnel evaluation. The MEMS sensors are designed in-house and fabricated out of house, and the shear sensors are a thermal type that are collocated with temperature and pressure sensors on a flexible polyimide sheet, which conforms to surfaces of a simple curvature. A total of 6 sensors are located within a 1.5 by 3 mm area as a cluster with each sensor being 300 μm square. The thickness of this sensor cluster is 75 μm . Outputs from the shear sensors have been compared with respect to those of the Preston tube for evaluation of the sensors on a flat plate. Pressure sensors are the absolute type and have recorded pressure measurements within 0.05 percent of the tunnel ESP pressure sensor readings.

The sensors and signal conditioning electronics have been tested on both a flat plate and a ramp in Langley's 15-Inch Low-Turbulence Tunnel. The system configuration and control PC is configured with LabView, where calibration constants are stored for desired compensation and correction. The preliminary test results are presented within.

Notes

Variable Radius Nacelle Studies
Active Shape Control Technologies for Engine Nacelle Lip Structure
David M. McGowan
National Aeronautics and Space Administration
Langley Research Center

An overview of the active shape control for a variable radius nacelle leading edge program is presented. The current technical plan and schedule will be discussed. Results from the structural shape change of curved plates demonstration will be presented, as well as the NASA LaRC concept for a variable radius nacelle leading edge. Results of a Boeing systems integration study of this concept will be discussed briefly. The status of the sensors, actuators, and computational design tools tasks will also be presented.

Notes

Variable Area Nozzle Development
Shape Memory Alloy Actuation for a Variable Area Fan Nozzle
Mike Larkin
Pratt & Whitney

The ability to control fan nozzle exit area is an enabling technology for next generation high-bypass-ratio turbofan engines. Performance benefits for such designs are estimated at up to 8 percent in thrust specific fuel consumption (TSFC) and 5 to 6 percent in range (or mission fuel burn) relative to current fixed-geometry engines. Conventionally actuated variable area fan nozzle (VAN) concepts tend to be heavy and complicated, with significant aircraft integration, reliability and packaging issues.

The goal of this effort was to eliminate these undesirable features and formulate a design that meets or exceeds leakage, durability, reliability, maintenance and manufacturing cost goals. A Shape Memory Alloy (SMA) bundled cable actuator acting to move an array of flaps around the fan nozzle annulus is a concept that meets these requirements.

In 1999, a full-scale sector model of this VAN system was built and then tested at the Jet Exit Test (JET) Facility at NASA Langley to demonstrate the system's ability to achieve 20 percent area variation of the nozzle under full-scale aerodynamic loads. In 2000, a closed loop position controller was developed and validated against full-scale loads at the JET Facility. Currently, flexible seal concepts to seal the nozzle flap-to-flap and other VAN-to-fixed structural elements are being examined. Potential seal materials are also being evaluated against chemical and temperature environment requirements. Finally, a durability test is in progress on the SMA bundled cable in the model at simulated full-scale loads.

Notes

CFD Design for Bypass Ratio 15 Nacelle Integration

William E. Milholen, II
National Aeronautics and Space Administration
Langley Research Center

A computational study is being conducted to evaluate the installation effects of ultra-high bypass ratio (BPR) nacelles on conventional twin-engine transonic transport aircraft. An unstructured Navier-Stokes flow solver, USM3D, is being utilized for the study. The results have been compared to wind tunnel data obtained in the NASA LaRC 16-Foot Transonic Tunnel, for nacelle BPRs of nine and twelve. The USM3D flow solver was found to adequately predict the flows of interest, and has subsequently been used to analyze the installation effects of a theoretical BPR-15 nacelle. In addition, a design code is being used in conjunction with USM3D to redesign the wing in the presence of the BPR-15 nacelle. The preliminary design results will be presented.

Notes

Computational Fluid Dynamics (CFD) Design of a Blended Wing Body (BWB) with Boundary Layer Ingestion (BLI) Nacelles

Melissa B. Morehouse
National Aeronautics and Space Administration
Langley Research Center

A study is being conducted to improve the propulsion/airframe integration for the Blended Wing-Body (BWB) configuration with boundary layer ingestion nacelles. Two unstructured grid flow solvers, USM3D and FUN3D, have been coupled with different design methods and are being used to redesign the aft wing region and the nacelles to reduce drag and flow separation. An initial study comparing analyses from these two flow solvers against data from a wind tunnel test as well as predictions from the OVERFLOW structured grid code for a BWB without nacelles has been completed. Results indicate that the unstructured grid codes are sufficiently accurate for use in design. Results from the BWB design study will be presented.

Notes

Integrated Components Technology Demonstrations Overview

Mary Jo Long-Davis
National Aeronautics and Space Administration
Glenn Research Center

Integrated Components Technology Demonstrations (ICTD) is a project under the Ultra-Efficient Engine Technology Program (UEET) as designated in the UEET Program Commitment Agreement. The ICTD Project will provide the opportunity to conduct technology demonstration tests of advanced turbine engine components (e.g., combustor, compressor, turbine, and materials) as part of an integrated system (TRL 6).

Initially, the major objectives of the Integrated Components Technology Demonstrations project are to

- Conduct component technology evaluation and system studies to determine, and prioritize, the most promising propulsion concepts, cycle, and architecture for a propulsion system with a Technology Availability Date of approximately 2010 and Entry Into Service of 2015.
- Determine the most attractive, cost-effective approaches for conducting the needed demonstration tests.
- Conduct demonstration tests of selected component technologies (i.e., 2200 °F CMC combustor liner and aspirating seal) in partnership with industry.

Notes

GE UEET Systems Study and Demonstration Plan

Jorge Seda
GE Aircraft Engines

To ensure a steady growth in airline travel and retain a pre-eminent U.S. position in the aerospace industry into the 21st century, aircraft passenger mile costs must be reduced while meeting more stringent environmental regulations. GEAE's UEET engine concept was designed to revolutionize the state of the art in propulsion technology with the biggest reduction in aircraft fuel burn, CO₂, NO_x, noise and Engine Related Operating Cost relative to a baseline engine. Multifunctional revolutionary engine technologies were carefully integrated to achieve the best balance between challenging and contradictory program goals with an EIS of 2015.

Notes

Pratt & Whitney UEET System Study and Demonstration Plan

Craig Nordeen
Pratt & Whitney

Pratt & Whitney has conducted an engine system and component study and concluded that a P&W geared turbofan will exceed all UEET requirements. A number of novel concepts have been identified that may exceed the current requirements by an even greater margin. The two phase technology demonstration plan is designed to prove component technologies that will enable future novel configurations.

Notes

Aspirating Seal Demonstration

Tom Tseng
GE Aircraft Engines

The performance benefits of using an aspirating seal compared to an existing labyrinth seal was verified through sub- and full-scale rig testing in the NASA Advanced Subsonic Technology (AST) Project, Contract No. NAS3-27720. This seal was designed for GE90 engine application at the low pressure turbine aft outer cavity seal location. The last phase of this program is to demonstrate the seal in the GE90 engine. This presentation is to brief the seal performance, engine test plan and status.

Notes

CMC Liner Demonstration
CMC Combustor Liner Demonstration
Mark Noe and Jim Steibel
GE Aircraft Engines

This program will demonstrate the cyclic durability of CMC combustor liners in a commercial engine application. The program includes the design, manufacture, rig test, and engine test of an inner and outer liner set. In addition, alternate methods of manufacture of the combustor liners will be investigated. To date, a liner set has been manufactured for a full annular rig test slated for the 4Q01. A liner set for engine demonstration will be completed this year with the cyclic durability engine test slated for 2002.

Notes

Environmental Impact Overview
Environmental Impact Assessment Sub-Project Overview
Catherine Peddie
National Aeronautics and Space Administration
Glenn Research Center

Aircraft emissions are deposited throughout the atmosphere, and at the lower stratosphere and upper troposphere they have greater potential to change ozone abundance and affect climate. There are significant uncertainties arising from the incomplete knowledge of the composition and evolution of the exhaust emissions, particularly regarding reactive trace species, particles, and their gaseous precursors.

NASA Glenn Research Center at Lewis Field has considered its role in answering these challenges and has been committed to strengthening its aerosol/particulate research capabilities with initial emphasis on establishing advanced measurement systems and a particulate database. Activities currently supported by the NASA Ultra-Efficient Engine Technology (UEET) Program and accomplishment up to date will be described.

Notes

Emissions Inventory
Aircraft Emission Inventories
Steven L. Baughcum and Donald J. Sutkus
The Boeing Company

We report on our recently completed three-dimensional (1° latitude by 1° longitude by 1 km altitude) inventory of global aircraft emissions (fuel burned, NO_x, CO, and total hydrocarbons) from scheduled air traffic for the year 1999. The methodology used to create this inventory is described and inventory results are presented. These results are compared with our previously published inventory of emissions for the year 1992, and the trends are discussed.

Notes

Turbine Chemistry Modeling

Modeling and Simulation of Trace Species Evolution Through a Turbine Passage

Nan-Suey Liu

National Aeronautics and Space Administration
Glenn Research Center

Thomas Wey

Taitech, Inc.

National Aeronautics and Space Administration
Glenn Research Center

Many of the engine exhaust species resulting in significant environmental impact exist in trace amounts. Recent research, e.g., conducted at MIT-ARI, has pointed to the intra-engine environment as a possible site for important trace chemistry activity. In addition, the key processes affecting the trace species activity occurring downstream in the air passages of the turbine and exhaust nozzle are not well understood. Most recently, an effort has been initiated at NASA Glenn Research Center under the UEET Program to evaluate and further develop CFD-based technology for modeling and simulation of intra-engine trace chemical changes relevant to atmospheric effects of pollutant emissions from aircraft engines. This presentation will describe the current effort conducted at Glenn; some preliminary results relevant to the trace species chemistry in a turbine passage will also be presented to indicate the progress to date.

Notes

PAGEMS

Particulate Measurements and Studies

Dan Bulzan

National Aeronautics and Space Administration
Glenn Research Center

Glenn Research Center has extensive instrumentation developed for measuring particulate and gaseous emissions. The Particulate and Gaseous Emissions Measurement System (PAGEMS) is a mobile facility housing advanced instrumentation used for measuring combustion particulates and gaseous species. Particulates sizes ranging from 10 nm to 10 μ m can be measured along with SO₂, NO, NO₂, CO, CO₂, THC and O₂. Measurements can be made from subatmospheric up to 60 atm. Representative data from two engine tests will be discussed. In one test, the fuel sulfur content was changed, while the other test (T-63 engine) used various fuel additives. Probe design is essential to acquiring accurate particulate data. I will discuss the AEDC designed particulate probe, and the results of a University of Minnesota calibration study using the probe. Another suite of instrumentation, a tunable diode laser (TDL), enables in-situ real time gaseous species measurements. Representative TDL data from a T-38 aircraft will be presented. In conclusion, near term measurement opportunities will be discussed.

Notes

DERA/NASA Collaboration
Combustor and Engine Exit Emissions Measurements
Rick Miake-Lye
Aerodyne Research, Inc.

Aircraft generated particles have become the focus of scientific studies to understand the effects of airplanes on the atmosphere. Both emitted particles and those generated behind the engines from condensable gases have been implicated in potential effects due to the formation of contrails and possible changes in cirrus cloud cover. Instrumentation has been developed to make detailed measurements of emitted particles (particle sizes, number densities, and size distributions) and particle precursor gases (SO_x and NO_y). A cooperative program with DERA (Qinetiq) in England has allowed measurements to be made at the exit of a combustor and at the exit of an engine using the same combustor technology. The results of these measurements will provide data for comparison to models and for input to global assessments of the impact of aircraft particle contributions to the atmosphere.

Notes